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Investigation of the Survivability of a Non-Ablative Aeroshell Composed of Carbon/Carbon Composites and Carbon Aerogel

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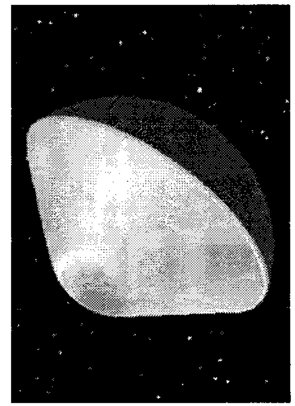
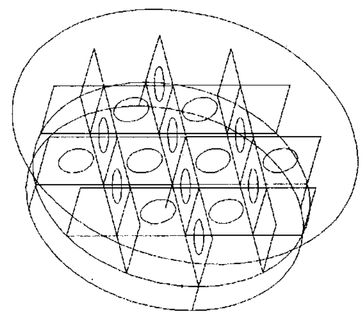
Non-ablative C-C Aeroshell

Introduction

- The survivability of an innovative Carbon/Carbon Non-ablative aeroshell structure design for the future NASA Mars and other Planetary entry missions was investigated.
- The aeroshell design composed of a SiC coated Carbon/Carbon (C/C) face sheets and C/C core structure with a carbon aerogel insulation layer.
- Arc jet tests for the represented model were performed under the simulated Mars entry heating conditions of scaled models.
- A thermal model was developed to effectively predict the thermal response of the C-C aeroshell to Mars entry conditions



aeroshell

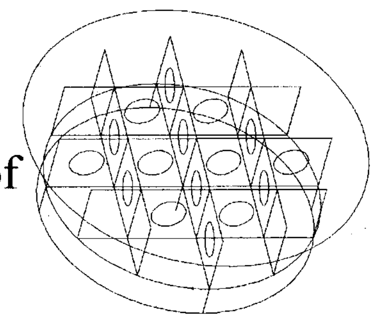


test model

Objective of the Arc Jet Test

- To verify the survivability of the proposed C/C non-ablative aeroshell structure and material in a simulated Mars entry condition:

1) Verify the thermal performance of the proposed aeroshell model.
2) Verify the design details of the aeroshell structure coating and bonding design.
3) Measure temperature of the face, interface and the back shell of the aeroshell structure.
4) Evaluate the thermal elastic response of the aeroshell structure based on the test data.



test model

Technology and Its Relevance to NASA Missions

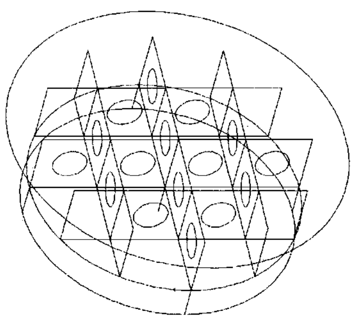
- Weight reduction and excellent thermal performance
- Suitable for Mars and Earth entry vehicle and thermal insulation structures.
- Technology could be flight ready for an '05 and beyond missions
- Collaborate with AMES for test model design and arc-jet testing

Non-ablative C-C Aeroshell

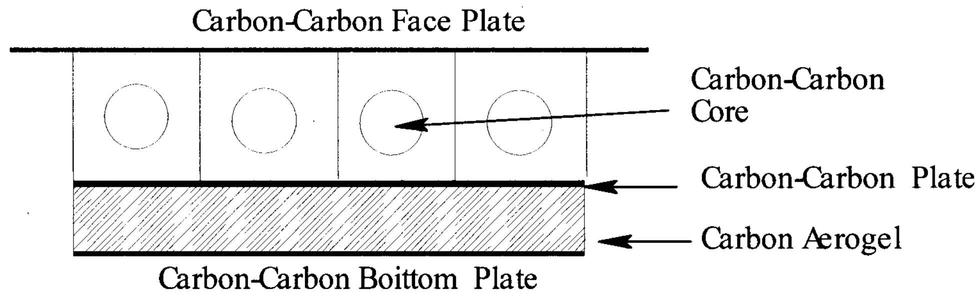
The Aeroshell model

The model is composed of

- a SiC coated C/C face plate
- a C/C Egg-crate core Structure
- a copper coated C/C radiation plate
- a carbon aerogel layer
- and a C/C back plate.

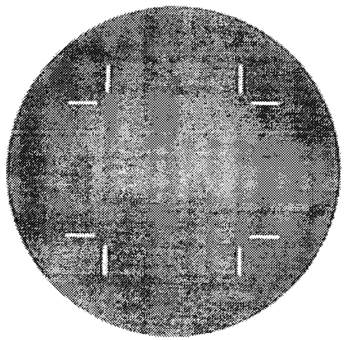


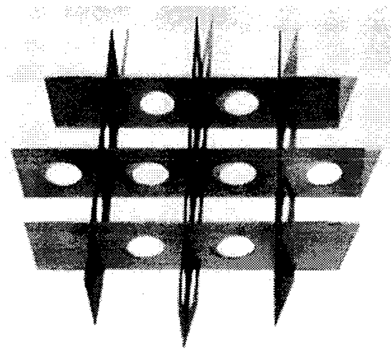
Perspective view

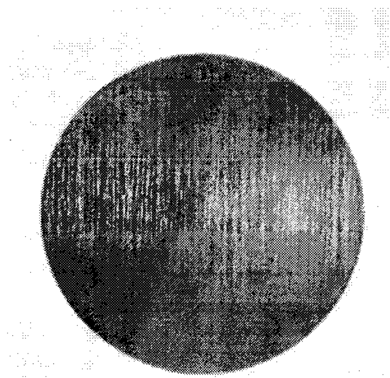


Side view

Fabricated Components and Model

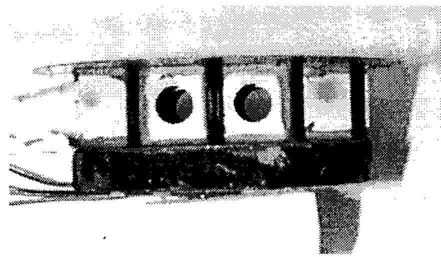

Sic Coated C/C face plate


Egg crate core


SiC Coated C/C plate


Copper coated C/C plate


Aerogel


Assembled model – (side view)

Carbon-Carbon and Carbon Aerogel Properties

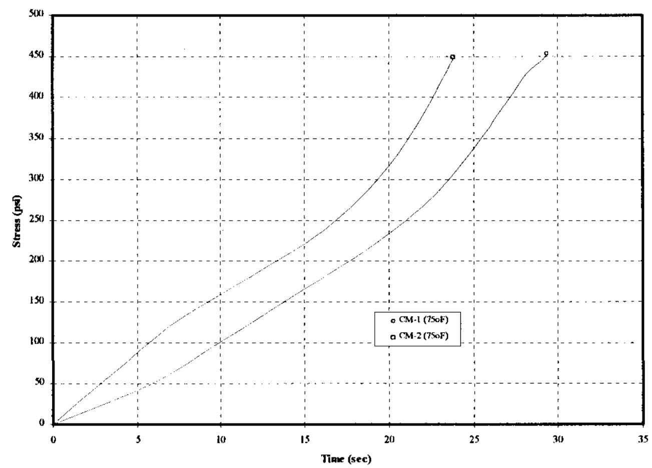
Property / Material	Quasi-isotropic C/C (13% Void Content)	Carbon Aerogel (at 25 C)	Unit
Density	1700.153	750.0	kg/m^3
E11	145.0	0.35	GPa
E22	145.0	0.35	GPa
G12	54.89	0.159	GPa
NU12	.3207	0.10	m/m
CTE11	-0.5e-06	0.2e-05	m/m/C
CTE22	-0.5e-06	0.2e-05	m/m/C
CTE66	.21e-14	0.2e-05	m/m/C
K11	110.3	.0220	W/m-K
K22	110.3	.0220	W/m-K
K33	10.88	.0220	W/m-K
Cp	628.124	700.0	J/kg-K

Carbon Aerogel

•Aerogels are a special class of open cell foams that have high porosity (>90%), ultrafine pore sizes (<50 nm), high internal surface area (400-1000 m^2/g) and a solid matrix composed of interconnected fibrous chains with characteristic diameters of 10 nm.

•Carbon aerogel specimen were prepared with four inches diameter and density of 0.07 g/cc.

•Compression strength of the 0.07 g/cc carbon aerogel was measured at three different temperatures, 21°C (75°F), 400°C (750°F) and 815°C (1500°F).



The Arc Jet Test

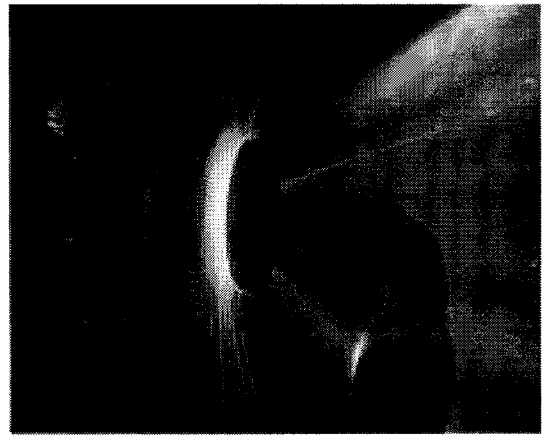
at NASA AMES Research Center

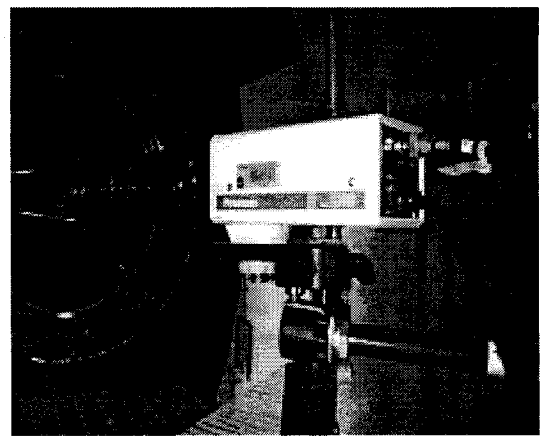
•The 60-MW Interaction Heating Facility (IHF) with the 13lh conical nozzle, was used for the Arc Jet Test.

•Carbon-Carbon Non-ablating test models were aerothermally tested at stagnation heat flux about 120 and 150 Btu/ft^{2}sec as measured on a 6 in flat-face probe and stagnation pressure about 40 and 48 mmHg

•Heating loads represent Mars Pathfinder Maximum heat flux

•Surface temperature data were obtained from Infrared pyrometers.





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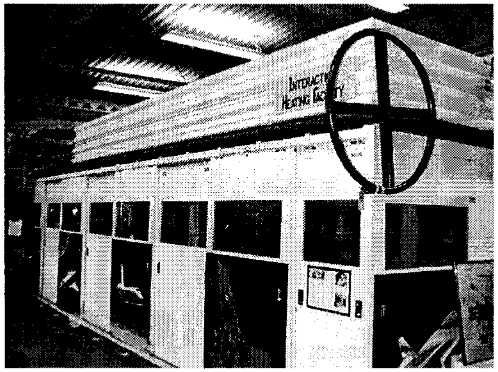
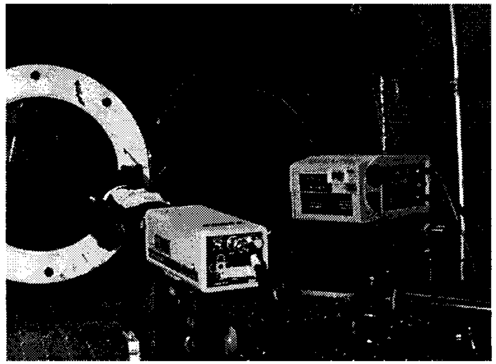
The Arc Jet Test (Cont.)

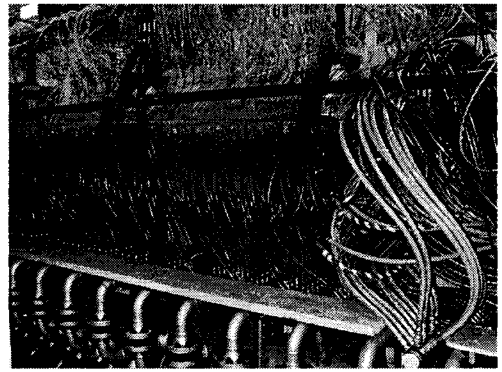
at NASA AMES Research Center



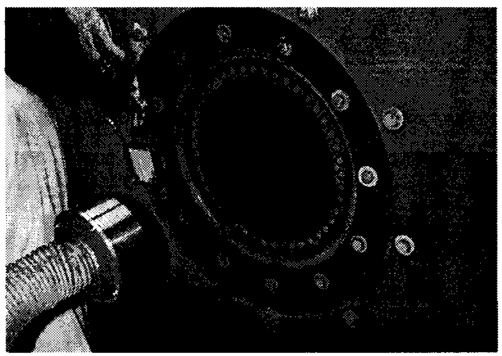
IHF facility (over view)



Laser Pyrometer

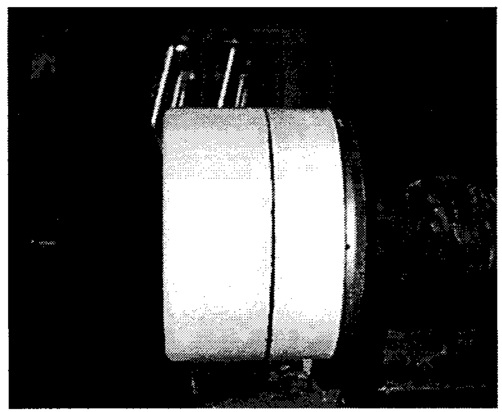


IHF facility (close view)



Jet nozzle outlet and model support

Picture of the testing



Model mounted in the test chamber

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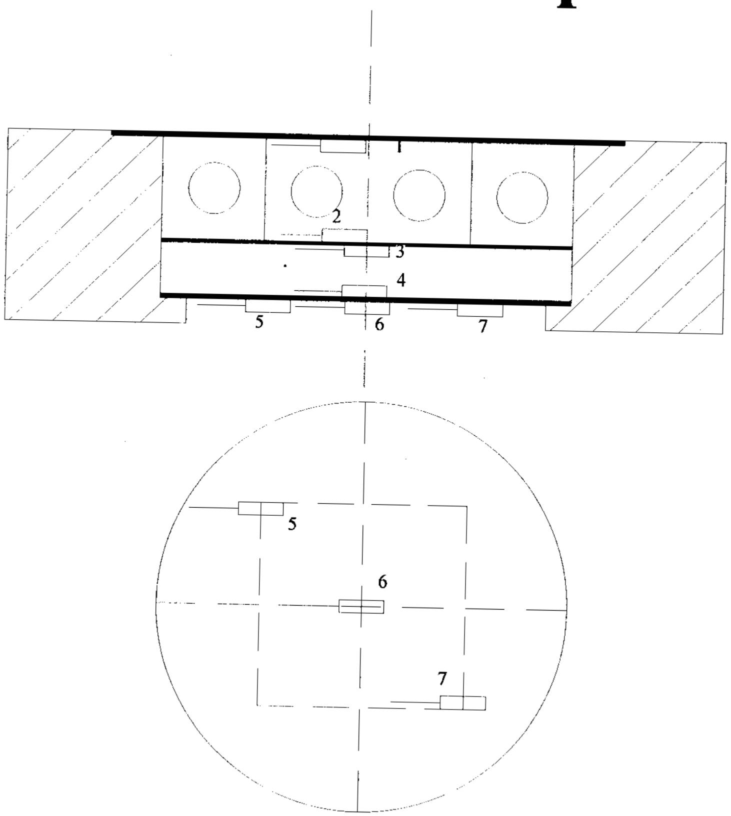
The Arc Jet Test Condition

	Aerodynamic Heating Facility		2- by 9-in. Supersonic Turbulent Flow Duct	Panel Test Facility	Interaction Heating Facility	
Nozzle configuration	Conical		2-dimensional	Semielliptical	Semielliptical	Conical
Gas	Air, nitrogen		Air, nitrogen	Air	Air	Air
Input power, (MW)	20		12	20	75	75
Nozzle exit dimension (in.)	12, 18, 24, 30, 36 (diameter)		2 × 9	4 × 17	8 × 32	6, 13, 21, 30, 41 (diameter)
Mach number	4		3.5	5.5	5.5	< 7.5
Bulk enthalpy (Btu/lb$_m$)	5000 to 14,000		1500 to 4000	2000 to 14,000	3000 to 20,000	3000 to 20,000
Type of test article	Stagnation point	Wedge	Flat plate	Wedge	Wedge	Wedge stagnation point
Sample size (in.)	8 (diameter)	26 × 26	8 × 10 8 × 20	14 × 14	24 × 24	18 (diameter)
Surface pressure (atm)	0.005 to 0.125	0.001	0.02 to 0.15	0.0005 to 0.05	0.0001 to 0.02	0.010 to 1.2
Convective heating rate (Btu/ft^{2}sec)	20 to 225	0.05 to 22	2 to 60	0.5 to 75	0.5 to 45	50 to 660
Radiative heating rate (Btu/ft^{2}sec)	0		0	0	0 to [illegible]	0 to 20

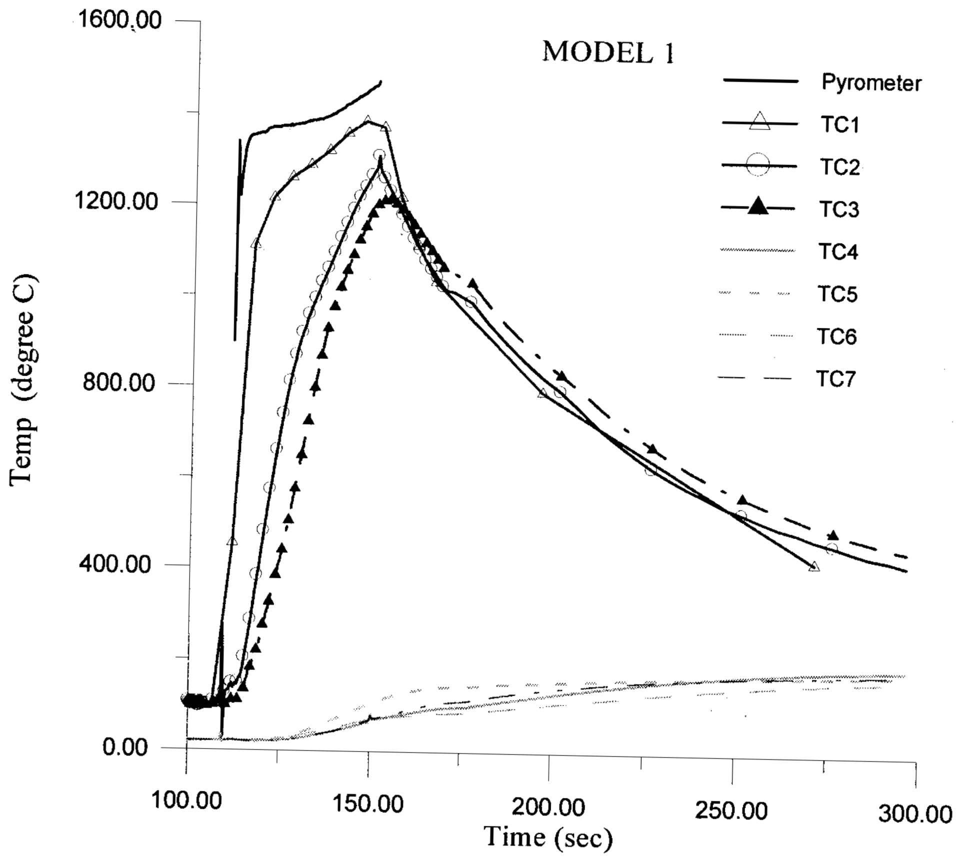
Non-ablative C-C Aeroshell

Example of the Test Results



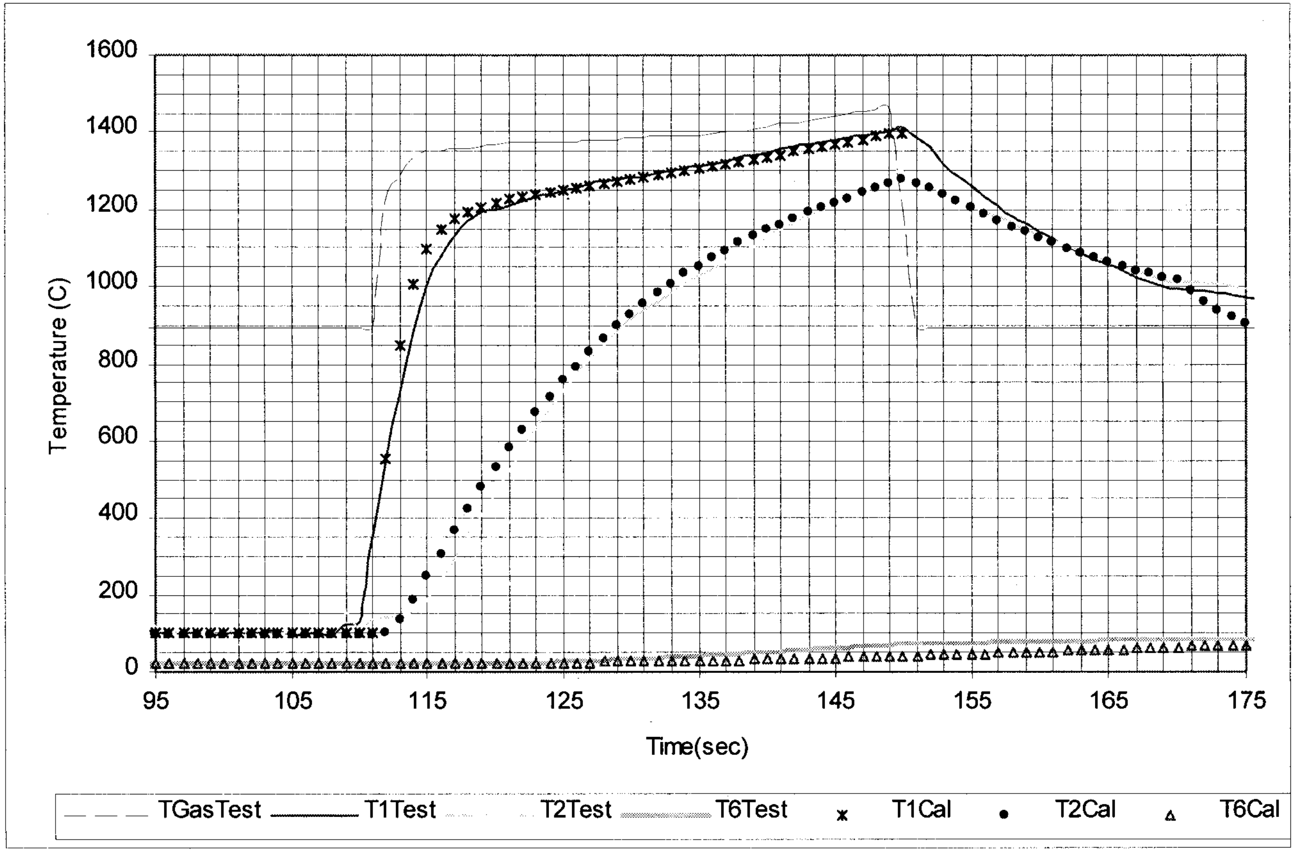
Thermocouple Arrangement for Nonablative Aeroshell Arc jet test

TC 1-3 ANSI B Type
TC 4-7 ANSI K Type



Non-ablative C-C Aeroshell

Thermal Modeling/Correlation



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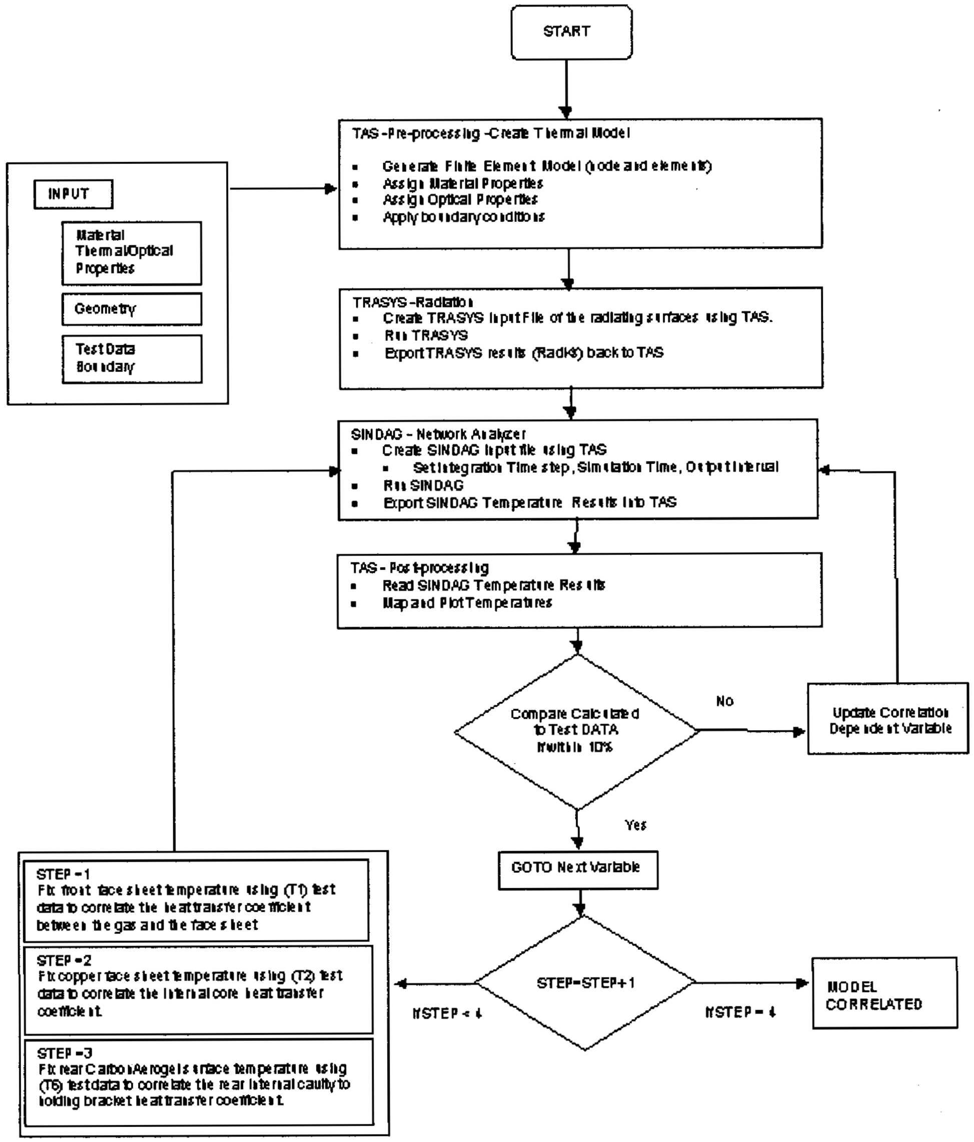
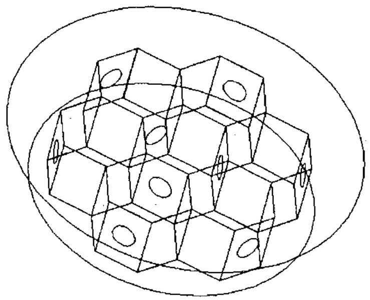
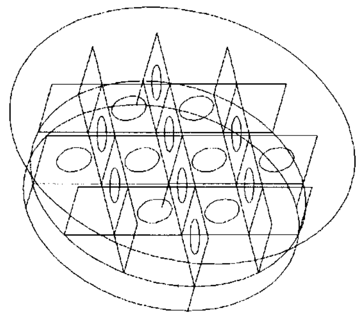
Thermal Modeling

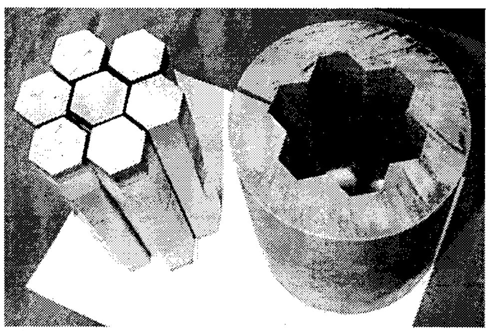


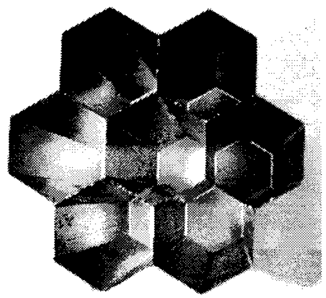
Non-ablative C-C Aeroshell

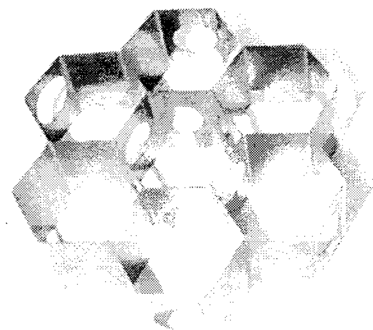
Configurations for Future Test











Honeycomb core tooling and sample

Second Phase Arc Jet Tests

- Second Set of Arc Jet Testing in Feb. 28 - March 3
- 12 new test models to be evaluated
- Additional test variables:
  - Two novel core designs
  - P-30 and XN-50 chosen as fibers for face sheet material, two different thickness/ply orientations
  - Two SiC coatings : CVI and Polymer SiC conversion
  - Two Aerogels to be evaluated

Concluding Remarks and Future Work

- An investigation of the the survivability of an innovative Carbon/Carbon Nonablative aeroshell structure for the future NASA Mars an other entry missions was performed
- The test results show the design provided significant thermal insulation with the interior surface being less than 100°C using Mars Pathfinder entry thermal profiles.
- The validity of the thermal performance of the proposed aeroshell model was proved through the correlation between the measured data and the thermal modeling.
- Alternative test models will be investigated through the scheduled Arc Jet test.
- High potential to reduced aeroshell structures mass has been demonstrated.
- Design Trade Studies to demonstrate mass quantities savings are recommended.